REPORT OF THE PCB WORKING GROUP

ONTARIO WASTE MANAGEMENT CORPORATION

1887-01
JANUARY 1989

DILLON
Consulting Engineers · Planners
Environmental Scientists

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90-02857/

1887-01

30 January 1989

Ontario Waste Management
Corporation
2 Bloor Street West
11th Floor
Toronto, Ontario
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Attention: Mr. J. Micak

Report of the PCB Working Group

Dear Sirs:

We are pleased to present our Final Report of the PCB Working Group. This report is the combined effort of M.M. Dillon Limited, Monenco Limited and VHB Research and Consulting Inc.

The Working Group report details the amount of PCB in existence in Ontario and the amount that is expected to go to the OWMC annually from 1992. We have also outlined technologies that must be added to the Facility in order that all PCB wastes can be accommodated at OWMC.

We have enjoyed conducting this study for you.

Yours truly,

M. M. DILLON LIMITED

C.M. Williams, B.Sc.
for J.R. Balfour, P.Eng. MCIP
Project Manager

CMW:mrb
Attach.

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REPORT OF THE PCB WORKING GROUP FOR THE ONTARIO WASTE MANAGEMENT CORPORATION ENVIRONMENTAL ASSESSMENT

1. INTRODUCTION

The Ontario Waste Management Corporation Draft Environmental Assessment (OWMC EA) report was reviewed by Ontario Hydro. Ontario Hydro expressed concern that the draft EA did not address the management of all aspects of waste containing PCB. In addition to waste management aspects detailed in the Draft EA, Ontario Hydro noted that the following wastes containing PCB were not addressed:

- transformer carcasses;
- capacitors;
- transformer bushings;
- other equipment such as electromagnets, regulators, switches, etc.

It is OWMC's intent to have the ability to manage all PCB wastes that will be generated in the Province. OWMC therefore established a Working Group to incorporate Ontario Hydro comments into a more comprehensive PCB waste management program.

The Working Group was mandated:

- to identify the quantities of PCB waste that are likely to be treated by OWMC and;

- to assess any technologies or modifications to the proposed facility design that would be required to accommodate all PCB wastes.

The PCB Working Group was set up with personnel from:

- OWMC
- Monenco Limited
- VHB Research and Consulting Inc.
- M.M. Dillon Limited

This report of the Working Group is divided into two main sections along the lines of the mandate given it by OWMC. Sections 1 to 3 deals with waste quantities; Section 4 and Appendix B deals with the technology for the treatment of the several types of waste containing PCB.

The first three sections of this report first identify the quantities of waste that exist now or will be generated in the future. Based on selected scenarios, the waste generation rate is then developed. The profile of the wastes containing PCB is such that it is appropriate to divide the discussion. It is expected that waste will originate from:

- high level PCB presently in service;
- low level PCB presently in service;
- PCB waste presently in storage
- PCB contaminated equipment.

This division is also appropriate because these different types of waste will require different waste management techniques.

The discussion of waste management technology is found in Section 4 and Appendix B of this report. These technologies were developed by Monenco Limited and have been presented, in Appendix B, as submitted to the Working Group.

2. PCB WASTE QUANTITIES

2.1 Background

PCB wastes present a specialized management problem for OWMC. PCB wastes are unusual in that they originate from the large scale use of a commercial product that is no longer being produced because new uses of PCBs have been curtailed by regulation (CEPA, Chlorobiphenyl Regulation No. 1, September 1977). As such, there is an identifiable quantity of waste likely to be produced and a relatively short-term management plan can be developed to deal completely with the wastes.

Another aspect of the PCB waste handling practices that is specialized is that ever since new uses have been curtailed, no comprehensive waste management plan has been approved. As a result, PCB entering the waste stream in the last ten years or more have only gone into secure storage. As well, PCB waste management practices have been closely strutinized by the public. Therefore, rigorous PCB destruction requirements have been developed by Government.

The continuing uses of PCB that are permitted under federal regulation are primarily in electrical equipment. PCB has been used in electrical equipment as coolants or dielectrics in a relatively pure fashion. Equipment designed to use PCB on average contains PCB diluted 30-35% with other chlorinated aromatic compounds. This diluted PCB and pure PCB oils are generically known as "askarel". This is the source of "high level" PCB presently in use and a component of the waste in storage. Low level PCB waste arises from past practices in which PCB was inadvertently mixed with other coolants, primarily mineral oil, and are found in non-PCB liquid-cooled

electrical equipment. Thus, low level PCB are found similarly in equipment in use and as fluids and in equipment in secure storage.

Equipment in use or storage will, in general, have PCB contamination after liquid PCB materials have been drained from them. As well, it is not feasible to remove PCB from some types of equipment - particularly electrical capacitors and fluorescent light ballasts. This accounts for the last type of PCB waste with which this report deals - PCB contaminated equipment.

In summary then, the PCB waste types are:

- high level PCB presently in service
- low level PCB presently in service
- PCB waste presently in storage
- PCB contaminated equipment

At present there are no PCB waste management facilities in Ontario that can handle all these PCB wastes. As a result, most of the PCB waste generated will likely require treatment by OWMC. Low level PCB wastes (mineral oil containing <7000 ppm) can be handled on a limited basis by approved companies in Ontario. Four companies are approved to treat these low wastes although they are technically limited to treating relatively clean mineral oils.

2.2 Total PCB Waste Quantities

In the sections that follow the development of PCB waste quantity data in each category is discussed. It is useful, however, to present the summarized findings of what follows so that the overall importance of each component is understood. Table 1 summarizes the existence of 32 100 tonnes of PCB distributed in over 166 000 pieces of equipment and storage containers.

TABLE 1
TOTAL PCB WASTE QUANTITIES

PCB LIQUID

		Tonnes
High Level (in use)		7 800
Low Level (in use)		13 300
Storage - high level		1 800
- low level		9 240
TOTAL PCB		32 100

PCB CONTAMINATED EQUIPMENT

			Units
High level (in use)	- transformers	4 768	
	- capacitors	55 079	
	- other	80	
		59 927	
			59 927
Low level (in use)	- transformers		91 400
Storage-high level	- transformers	1 282	
	- capacitors	13 296	
-low level	- transformers	378	
		14 956	14 956
	TOTAL UNITS		166 300

It is noted here that this PCB waste inventory does not include the OWMC class of waste called "decommissioning wastes". Typical of this class of waste not discussed in this report are:

- Collected wastes at the former Chemical Waste Management site in Smithville now controlled by the Ministry of the Environment and destined for on-site treatment at Smithville.

- Contaminated soils found for example at the Pottersburg Creek waste site in London.

2.3 High Level PCB in Service

The quantities of high level PCBs, or askarel, that are in service, in Ontario, were derived primarily from the Environment Canada Inventory of PCB Equipment in Use (Environment Canada, 1988). The inventory was developed as a result of voluntary submissions by PCB owners. It is considered to be a comprenensive inventory, current as of June-July 1988. The inventory quantities received from Environment Canada, did not include the quantities of PCB owned by Ontario Hydro. Ontario Hydro's inventory was, therefore, obtained separately from them (Ontario Hydro, 1988).

The askarel quantities in service in Ontario are shown in Table 2. The quantities shown are a summation of the Environment Canada Inventory quantities and Ontario Hydro's holdings. It is important to remember that these estimated quantities are for high level PCB liquids contained in equipment in use. Data for the liquid mass was estimated for

TABLE 2

QUANTITIES OF HIGH LEVEL PCBs (ASKARELS) IN USE IN ONTARIO (JUNE-JULY 1988)

Equipment Type	Number of Units	Quantity (tonnes)
Transformers	4 768	7 246
Capacitors	55 079	530
Other	80	41
TOTAL IN SERVICE	59 927	7 800

Reference: Environment Canada Inventory of PCB Equipment in Use, July 1988.

Ontario Hydro Inventory of In-Service Equipment, August 1988.

individual units (it is assumed by the individuals volunteering their own data) and aggregated up to the total. Information in both databases was reported as litres of PCB. Managers of the databases are unsure whether quantities were reported as 'litres' or other equivalent fluid volume, or were reported by weight and converted using standard conversion factors. This may have a bearing on the validity of the quantity values shown for PCBs in capacitors. For waste management purposes, the quantity of PCBs from capacitors should be reported as the weight of PCB plus capacitor casing as capacitors must be destroyed as an entire unit. Therefore, it is possible that the quantities of PCB reported, in Table 2, for capacitors are underestimated.

It should be noted that existing inventories of in-service equipment have not included any estimates of the quantity of PCB contained in fluorescent light ballasts. Therefore, no estimation has been presented here. A range estimate for the number of ballasts in-service and the associated PCB quantities is shown in Table 6 and discussed in Section 2.6.

As can be seen the majority of high level PCBs are contained in electrical transformers. There are a large number of electrical capacitors in use in Ontario, over 55 000. These capacitors contain small quantities of PCB relative to transformers. This electrical equipment must eventually be taken out of service and managed as PCB waste.

2.4 Quantities of Low Level PCBs in Service

The electrical equipment described in Section 2.3 was designed to contain askarel. PCB concentrations average 65-70% of the contained liquid. These transformers, etc.

used askarel because of its electrical and coolant properties, and, because of the fire protection afforded by its non-flammability. Many more transformers exist in electrical distribution system that do not need the fire protection rating offered by askarels and were designed to use mineral oil coolants.

Some oil filled electrical equipment was contaminated inadvertently with PCB. This was due primarily to historic manufacture and maintenance practices. It has been estimated that approximately 10 percent of all oil filled electrical equipment is contaminated with greater than 50 mg/kg (ppm) PCB with concentrations usually being less than 1 000 ppm in the oil. Under Ontario law this contaminated oil with >50 ppm PCB is designated a PCB waste when it is removed from service and must be managed appropriately. As such an estimate of the total quantity of PCB contaminated oil in Ontario has been developed.

Under existing law there has been no requirement to identify and inventory PCB contaminated equipment. Therefore, there are no inventories of PCB contaminated oil in existence. Only when a dedicated identification program was undertaken is reliable data produced. Some electrical utilities in Ontario have undertaken to identify how much contaminated oil they own.

For this study, all Municipal Electrical Utilities were contacted through the help of the Municipal Electrical Association (MEA). The following utilities have volunteered their data on mineral oil contamination:

- Ontario Hydro
- Toronto Hydro
- London Public Utilities Commission

This available inventory information was used to develop an estimate of the total quantity of contaminated oil in Ontario.

It is recognized that Ontario Hydro is a unique electrical utility in that it generates the majority of the electrical power in the Province and provides the power, transformed to reasonable voltages, to the Municipal Electrical Utilities. As such, Ontario Hydro owns much more electrical equipment, and accordingly, contaminated oil, than the municipal utilities. Therefore the contaminated oil holdings of Ontario Hydro were not used as a factor for estimating the quantities owned by the municipal utilities in general. It was felt, however, that the quantities of contaminated oil owned by Toronto Hydro and London PUC were fairly representative of the quantities owned by the 75 municipal utilities in Ontario.

In order to extrapolate from the quantities of contaminated oil held by Toronto Hydro and London PUC, two statistics were examined:

1. Ontario Hydro sales of power to municipal utilities (Ont. Hydro 1987): It was felt the amount of electricity used, as described by Ontario Hydro sales of power to municipal utilities, would bear a relationship to the amount of installed electrical equipment. Thus a correlation between sales and contaminated mineral oil holding might also exist.

2. Number of customers: The total number of residential and industrial customers of the municipal utilities could bear a similar relationship to electrical equipment ownership and therefore contaminated oil holdings.

Both statistics were evaluated for Toronto Hydro and London PUC and total mineral oil holdings in the municipal section in Ontario were developed by grossing up the statistics from Toronto and London data to the whole set of 75 municipal utilities.

The estimated quantities of contaminated oil in service in Ontario is provided in Table 3. The number of units and total mass of PCB contaminated liquid for Ontario Hydro was provided from Hydro's inventory data. The municipal utilities' quantity was developed as described above, both for the number of units and the mass of the contained liquid. Note that an additional estimate has been included to account for private holdings of contaminated oil. It is known that many private companies own oil-filled electrical equipment that may be PCB contaminated. As at this study date, there are no known inventory estimates of PCB contaminated oil holdings within the private sector in Ontario. As such, it has been estimated that the private sector owns 20% of the PCB contaminated oil owned by the Ontario Utilities.

The greater number of units in the rural system (Ontario Hydro) compared to the urban systems reflects the greater distance in the countryside and the larger number of local transformers per capita.

To test the validity of the above estimate, the rate of transformer contamination was factored against an estimation of the total number of installed oil filled transformers in Ontario - Table 4. As discussed above, it has been found that approximately 10% of all oil filled equipment has been contaminated with >50 ppm PCBs. This rate was used as a factor in Table 4. The data support the order of magnitude of our initial estimate.

TABLE 3
ESTIMATED QUANTITIES OF LOW LEVEL PCB
IN USE IN ONTARIO - FROM INVENTORY
(Mid-1988)

Owner	Units	Quantity (tonnes)
Ontario Hydro	65 650	5 360
Municipal Utilities	10 500	5 680
Private Owners (20% of Utility Quantities)	15 200	2 230
TOTAL	91 400	13 300

Reference: M.M. Dillon, August 1988.

TABLE 4

ESTIMATED QUANTITIES OF LOW LEVEL PCB IN USE IN ONTARIO - FROM CONTAMINATION RATE (mid - 1988)

Transformer Type	Estimated No. In Use	Estimated Number Contaminated (@ 10%)	Liquid-Average Mass (kg)	Total (tonnes)
Small distribution transformers Up to 225 kVA	1 200 000	120 000	60	7 200
Transformers Larger than 225 kVA	200 000	20 000	900	18 000
		140 000		25 200

Reference: M.M. Dillon, August 1988.

These two estimates are fairly close particularly considering that the 25 200 tonne estimate does not take into consideration that equipment has been taken out of service (approximately 9,200 tonnes. See Section 2.5). As such the more conservative estimated total quantity of 13 300 tonnes PCB contaminated oil has been used for the purposes of this study.

2.5 PCB Waste Quantities in Storage

PCB waste quantities have been derived from the Ontario Ministry of the Environment (MOE) 11/82 PCB Inventory (MOE 1988). The inventory is a compilation of all PCB wastes reported to be in storage in Ontario, as required under Ontario Regulation 11/82. The inventory is current as at June 1988. PCB waste quantities are shown in Table 5. The reported quantities of PCB in fluorescent light ballasts may be anomalously high. This is because ballasts quantities were reported to MOE by numbers of drums only. MOE assumed a weight of 200 kg per drum of ballasts in order to estimate a PCB quantity for this item. The study team feels that 200 kg PCB drum of ballast may overestimate the quantity of PCB actually present.

It should be noted that the PCB waste quantities shown do not include the quantities of PCB contaminated soil currently in storage or the quantities of waste at the Smithville storage facility controlled by MOE. For the purposes of this study, and, the OWMC EA, PCB contaminated soil has been considered a 'decommissioning waste' and is discussed under separate cover. MOE is intending to destroy all wastes at their Smithville facility in 1990. Therefore, they will not require disposal at OWMC.

TABLE 5
PCB WASTE QUANTITIES IN STORAGE
(June 1988)

High Level PCBs

Equipment Type	Number of Units	Quantities (tonnes)
Transformers and bulked liquids	1 282	996
Capacitors	13 296	212
Ballasts	-	525
Other Solids	-	68
SUB-TOTAL	14 578	1 800

Low Level PCBs

Transformers	378	9 174
Capacitors	-	-
Other	-	58
SUB-TOTAL	378	9 232
TOTAL	14 956	11,000

Reference: Ontario Ministry of the Environment Regulation 11/82 PCB Waste Inventory, July 1988.

2.6 PCB Contaminated Equipment

In the foregoing, mass quantities of liquid PCB were developed for high and low level concentration categories. Equipment (number of units) was also identified. From that data, the number of units that will appear in the waste stream can be summarized.

The number of units will arise primarily from the askarel (high level PCB) equipment. This results from the supposition that equipment containing low level PCB contaminated oil will likely be readily decontaminated with the carcass of the equipment being re-used or sent to available scrap processors. There are guidelines in existence in Ontario that allow this decontamination. The number of units that will have to receive some treatment is provided in Table 6.

In Table 6, an inventory item called ballasts is identified. Ballasts are electrical devices used in the operation of fluorescent light fixtures. Dillon has estimated that some 900 tonnes of PCB exists in light ballasts in Ontario (Dillon 1983). Ballasts are relatively small units with 0.023 to 0.40 kg of PCB in a solid insulating molding. Individually, they do not qualify as PCB waste (mass exemption) but often they are collected in quantity as a result of maintenance practices. Ballasts collected by large organizations must be managed as PCB waste in a similar manner to other electrical capacitors.

Another type of PCB contaminated equipment is PCB contaminated lead cable. In early 1988, Toronto Hydro discovered that they had lead transmission cable in their underground network system that had inadvertently been

TABLE 6
NUMBER OF PIECES OF PCB CONTAMINATED EQUIPMENT

	Units	Units	Units	
In Use:				
Transformers	4 768			
Capacitors		55 079		
Other			80	
In Storage:				
Transformers	1 282			
Capacitors		13 296		
TOTAL UNITS	6 050	68 375	80	74 505
Ballasts:		2 250 000 - 30 000 000 units		
Lead Cable		1 000 - 1 500 km.		

contaminated with PCB. This cable has a lead exterior and is filled with insulating batting. It is the insulation that has been contaminated.

Toronto Hydro has isolated the source of the contaminated cable as being a sealing compound which they purchased in the 1950s and 1960s. They also have found that the contaminated cable is only found in their underground network. Therefore, the only other utilities that could have contaminated lead cable are Ontario Hydro, London PUC and Ottawa Hydro.

Toronto Hydro has estimated that they have approximately 500 km of PCB contaminated cable in their network system. Ottawa Hydro has tested their cable and found that none of it is contaminated. They have also researched their records and found that they never purchased the suspect sealing compound. Neither London PUC or Ontario Hydro have tested their in-service cable. Both utilities suspect, however, that some of their cable is PCB contaminated.

As the exact quantity of PCB contaminated lead cable is unknown, the study team has estimated that 1000-1500 km of PCB contaminated lead cable will require disposal as a PCB waste.

2.7 Regional Distribution of PCB Quantities

To assist in the transportation risk assessment, it is necessary to disaggregate the total PCB quantities down to a county level. The inventory data used above to develop total quantities was used as the basis for the disaggregation into counties. The manner in which the disaggregation was accomplished is described below.

2.7.1 Disaggregation of High Level PCB Quantities

Three sources of data were used: Ontario Hydro Inventory of askarel in use, Environment Canada Inventory of Askarel in Use and MOE Inventory of PCB Waste. Note that the Environment Canada data did not include Ontario Hydro data.

Ontario Hydro provided their inventory by individual locations. Therefore, the askarel in use in each county was available by adding the quantities found in each county.

Similarly, the MOE PCB Waste Inventory was broken down into individual sites so the county totals were available by adding all the high level PCB wastes found in each location within each county.

The Environment Canada data was not as amenable to simple summations. It was presented only as aggregate quantities by Ontario MOE Region. To disaggregate each of these Regional amounts into counties, two statistics were used:

1. Manufacturing value added - data-available on a county basis;

2. Number of residents - data on population.

The portion of each county's manufacturing value added and population as a proportion of the totals for the Region was used to estimate the county's PCB relative to the known total. These two estimates were then averaged to produce a final estimate for the Environment Canada proportion. This disaggregation method was felt to be reasonable as it is well

recognized that power generation and thus PCB ownership is a function of industry and population in a given locale. This technique has also been used in other OWMC studies.

Finally, the three components for each county were summed to produce the total quantity of high level PCB. This appears in Column 1 of Table 7.

2.7.2 Disaggregation of Low Level PCB Quantities

The low level PCB quantities were estimated from two data sources: the MOE PCB Waste Inventory and the estimate of low-level PCB in-use developed previously in this work.

The MOE data, as before, is identified by site so that county totals were readily available.

Similarly, the municipalities were identified with counties and county totals were then developed.

The county totals were produced by adding these two components, see Column 2 in Table 7. It is noted that the totals do not include any low level PCB owned by Ontario Hydro as that agency has expressed the intention to decontaminate all of its own low level PCB waste. The totals also do not include the quantities of low level PCBs estimated to be owned by the private sector. There is no information available on the regional distribution of privately owned PCB contaminated equipment.

It should be noted that the disaggregated quantities do not quite correspond to the totals shown in Table 1. This is primarily due to 'rounding error' in the disaggregation calculation and to the fact that many of the counties have

TABLE 7

PCB QUANTITIES BY ONTARIO COUNTIES

Municipality, County or District	High Level PCB Quantity (Tonnes)	Low Level PCB Quantity (Tonnes)*	Total Quantity (Tonnes)
Middlesex	186	233	419
Essex	328	239	567
Kent	59	57	116
Bruce	352	14	366
Oxford	70	50	120
Huron	32	4	36
Grey	42	10	52
Elgin	36	1	37
Perth	32	2	34
Hamilton-Wentworth	697	290	987
Niagara	576	313	889
Wellington	222	64	286
Dufferin	16	-	16
Haldimand-Norfolk	432	-	432
Waterloo	460	263	723
Brant	140	69	209
Toronto (Metro)	1 808	10 669	12 477
Durham	231	585	816
Peterborough	58	228	286
York	200	194	394
Simcoe	96	65	161
Halton	128	184	312
Peel	363	384	747
Haliburton	10	-	10
Muskoka	29	12	41
Northumberland	49	25	74
Victoria	22	2	24
Frontenac	93	100	193
Leeds & Grenville	61	17	78
Ottawa-Carleton	222	448	670
Stormont, Dundas & Glengarry	73	3	76
Hastings	70	49	119
Prescott & Russell	25	2	27
Lanark	21	-	21
Renfrew	26	1	27
Lennox & Addington	141	-	141
Sudbury	353	130	483
Algoma	447	17	464
Cochrane	269	2	271
Temiskaming	97	2	99

TABLE 7
PCB QUANTITIES BY ONTARIO COUNTIES
(Continued)

Municipality, County or District	High Level PCB Quantity (Tonnes)	Low Level PCB Quantity (Tonnes)*	Total Quantity (Tonnes)
Nipissing	156	48	204
Parry Sound	76	2	78
Manitoulin	13	-	13
Thunder Bay	419	143	562
Kenora	121	8	129
Rainy River	93	3	96
Prince Edward	8	1	9
Lambton	142	47	189
TOTAL	9 600	14 980	24 580

* County totals do not include the quantities of low level PCBs owned by Ontario Hydro or the private sector.

very small quantities of PCB - less than one tonne. These counties have been given a minimum quantity of 1 tonne in this assessment. These two factors account for the small variation.

3. RATE OF WASTE GENERATION

As discussed above, much of the PCB waste in the future will come from the removal of electrical equipment containing PCBs from service. Consideration must be given to equipment attrition rates when estimating the rate at which PCB waste that will be generated annually. Annual PCB waste rate quantities have been developed separately for:

- high level PCBs in service;
- low level PCBs in service and stored as waste;
- high level PCBs in storage as waste.

The details of the scenarios used to generate the waste rates are given in the sections that follow. By way of summary, the estimates are presented in Table 8.

The annual PCB waste quantities have been based on the total quantity of PCB in Ontario with consideration for phasing out equipment and waste at a reasonable rate. Not all of the PCB wastes, specifically low level PCBs, generated each year will be disposed at OWMC. Some low level PCB contaminated oils will likely be decontaminated on-site using existing approved technology. OWMC is planning to accept all PCB wastes not otherwise managed. This includes PCB contaminated equipment carcasses which will be discussed below.

3.1 Generation Rate for High Level PCB Waste (From Service)

As shown in Table 1 there are 7 800 tonnes of PCBs (askarel) in operating electrical equipment in Ontario. When this equipment is removed from service, it becomes PCB waste. A

TABLE 8

ESTIMATED RATE OF PCB WASTE GENERATION

Waste Type	Total Quantity Available (tonnes/year)	Potential Quantity to OWMC (tonnes/year)
High Level PCBs	400-700	400-700
• remove from service 1992-future		
Low Level PCBs	2 800	900-1 400
• removed from service and waste in storage		
High Level PCB Wastes	670	670
• in storage pre 1992		
TOTAL	3 870-4 170	1 970-2 770

scenario was, therefore, developed to determine how much PCB electrical equipment would be removed from service in a given year. For the purpose of this study two scenarios were used. These are:

1. All equipment is removed from service under natural attrition (when the equipment has reached the end of its useful life). The removal from service is assumed to take place between 1989 and 2007.

2. Approximately 14% of all transformers from high priority locations will be removed on an accelerated schedule over a five year period with the remainder being phased out by attrition. The accelerated removal from insecure service is assumed to take place between 1993 and 1997 when OWMC facilities would be available.

These scenarios were among those developed for Environment Canada and have been adopted by the Canadian Council of Resource and Environment Ministers (CCREM, 1987) as a reasonable approach for removing PCB from service.

Recent events have led the government to consider the extremely accelerated phase-out, over a five year period, of PCB from service (Toronto Star, September 8, 1988). It has not been confirmed whether this accelerated phase-out will be adopted. As such, a five year phase-out of PCB from in-service equipment has not been considered here.

The attrition and accelerated phase-out models used in this study were derived from the CCREM PCB Phase-Out Strategy-Control Options Report (Preliminary) and are detailed in Appendix A. The scenario models have been used to estimate the number of transformers and capacitors and the quantity of

PCB that will be taken out of service each year based on the age and size of the equipment. Only capacitors and transformers were used as they comprise over 99% of the askarel equipment that is still in service in Ontario.

Under the natural attrition scenario, the model estimated that, on average:

- 180 transformers; and
- 1 750 capacitors

will be taken out of service annually until the year 2007. This equipment is estimated to contain:

- 400 tonnes/year

of PCB. The maximum quantity of PCBs that is estimated to be generated due to equipment attrition is 454 tonnes/year. This maximum occurred in only one year and in most instances, annual quantities are estimated to be around 400 tonnes.

Accelerated phase-out scenarios show, as can be seen in Table A.4, that annual quantities could be as high as 700 tonnes/year if an accelerated phase-out program, of the type described, is put into place. As such, a range of quantities of 450-800 tonnes/year has been used in Table 8.

It should be noted that under the scenarios presented, the maximum rate of 800 tonnes/year would only occur for five years after which time the annual rate would decrease to a maximum of 400 tonnes/year.

It has been assumed that 100% of this high level PCB will go to OWMC as at January 1989 there are no other facilities in Ontario to accept it. Out-of-province PCB destruction

facilities, Swan Hills in Alberta and the proposed Selenco Facility in Quebec, will not be able to accept out-of-province PCB waste according to current government directives.

3.2 Generation Rate for Low Level PCB Waste

As with askarels, the majority low level PCBs are contained in electrical equipment that must be removed from service. The electrical utilities have indicated, however, that they are willing and interested in retiring contaminated oil-filled equipment at an accelerated rate. This is primarily because the oil can easily be drained from the transformer and the transformer carcass can be decontaminated and returned to service or disposed as non-PCB scrap. It is much more difficult to do this for askarel equipment.

The major electrical utilities have stated that they are interested in removing the PCB contaminated oil from their in-service equipment. They would like to have this completed in 10 years (Ontario Hydro, Toronto Hydro).

The other major factors that will determine the amount of contaminated oil available for destruction at OWMC in 1992 and the OWMC market share after that time are:

- Ontario Hydro is planning to decontaminate their 5 360 tonnes of contaminated oil with their own in-situ process. Therefore, the Ontario Hydro oil has not been considered for destruction at OWMC.

- There are four companies decontaminating oil in Ontario. Data provided by these companies suggest that they are

capable of treating 3 000 tonnes of oil per year. However, their record over the last eighteen months collectively has been of the order of 500 tonnes total or 330 tonnes per year. It is assumed therefore that treatment by private companies will average 1 000 tonnes per year.

Based on these factors, it has been estimated that 3 000 tonnes of the approximately 17 250 tonnes of oil in existence in Ontario (excluding Ontario Hydro) will be destroyed by 1992. This leaves approximately 14 250 tonnes available for destruction in 1992. The private oil treaters have also estimated that, at present, about an eight year market exists for their business. This means that at the beginning of 1992, the 14 250 tonnes available for treatment will be managed in the five years to the end of 1996 at a rate estimated to be 2 800 tonnes per year. All PCB contaminated transformer oil will be destroyed by 1997 and there will be no further inventory after that date.

The market share that the existing decontamination companies will maintain after 1992 is unknown. It is recognized that the costs to destroy this oil at OWMC will probably be less than to decontaminate it. This is because the oil will provide good fuel value to the OWMC incinerator. American experience has shown that the decontamination companies have maintained a share of the market even though incineration is available. Therefore, it has been assumed that OWMC will receive 1/3 to 1/2 of the contaminated oil available after 1992. This would involve destruction of an estimated:

- 900-1 400 tonnes/year

of PCB contaminated oil at OWMC.

3.3 Generation Rate for High Level PCB Wastes in Storage

For the purposes of this study, it has been assumed that all PCB waste will be removed from storage and destroyed over a five year period from 1992. It was felt reasonable to destroy the stored wastes on a more accelerated schedule as much of the waste has been in storage for a long time and some storage facilities are not as secure or well inspected as in-service installations (St. Basile). Therefore an estimated at 580 tonnes per year of PCB waste will be available for treatment. This estimate is comprised of the following quantities:

High level waste in storage (Table 5)	1 801
High level waste projected (Table A.5)	1 530
	3 331 tonnes

or 670 tonnes/year

This 670 tonnes/year is comprised of only high level PCB wastes. This figure includes all high level wastes currently in storage plus the estimated quantity that will be removed between now and 1991 as shown on Table A.5. The low level waste oil quantities have been included in the discussion above. It has, therefore, been assumed that no destruction for these high level wastes or oils will be available before 1992 and that OWMC will be the only facility capable of destroying them. Therefore, it has been assumed in Table 8 that OWMC will receive 100% of the 670 tonnes/year of high level PCB wastes.

3.4 Generation Rate for PCB Contaminated Equipment

As discussed above, electrical equipment carcasses, particularly from transformers, and electrical capacitors that are contaminated with PCBs, will be generated and must be managed as PCB waste. It is estimated that:

- 400 transformers
- 4 500 capacitors

will be generated as waste from attrition and storage each year. These transformers and capacitors are contaminated with askarel.

Low level contaminated equipment will generally not require management at OWMC or other hazardous waste facilities. This is because the majority of the equipment will be retrofilled with clean oil and released or scrapped as non-PCB waste according to an approved process (Ontario Hydro, Toronto Hydro).

There are currently no facilities in existence in Canada to destroy PCB capacitors and other PCB contaminated metals to destroy PCB capacitors. Therefore a PCB decontamination facility has been designed to accommodate all PCB contaminated equipment carcasses and metals that are smaller, or equal in size to a 10 MVA transformer. The facility design is discussed in Section 3 and Appendix B of this report.

Their numbers were estimated in Section 2.6 (Table 6) and their decontamination is assumed to be spread over the 15 year period from 1993 to 2007.

3.5 Regional Distribution of PCB Annual Generation Rates

To assist in OWMC systems design, the annual quantities of PCBs that are expected to go to OWMC have been identified for each Ontario county. These quantities are shown in Table 9. The annual quantities being transported from each county have been apportioned based on the percentage of PCB in each county as shown in Table 7 as compared to the whole province. The annual quantities shown assume that the highest quantities, shown in Table 8 will removed each year.

TABLE 9
ESTIMATED PCB QUANTITIES (HIGH AND LOW LEVEL) TRANSPORTED TO OWMC PER YEAR

County	PCB Quantity (tonnes/year)
Middlesex	48
Essex	65
Kent	13
Bruce	42
Oxford	14
Huron	4
Grey	6
Elgin	4
Perth	4
Hamilton-Wentworth	113
Niagara	101
Wellington	33
Dufferin	2
Haldimand-Norfolk	49
Waterloo	83
Brant	23
Toronto (Metro)	1 422
Durham	93
Peterborough	33
York	45
Simcoe	18
Halton	36
Peel	85
Haliburton	1
Muskoka	5
Northumberland	8
Victoria	3
Frontenac	21
Leeds & Grenville	9
Ottawa-Carleton	76
Stormont, Dundas & Glengarry	8
Hastings	13
Prescott & Russel	3
Lanark	2
Renfrew	3
Lennox & Addington	16
Sudbury	55
Algoma	53
Cochrane	31
Temiskaming	11
Nipissing	22
Parry Sound	8

TABLE 9
ESTIMATED PCB QUANTITIES (HIGH AND LOW LEVEL) TRANSPORTED TO OWMC PER YEAR
(Continued)

County	PCB Quantity (tonnes/year)
Manitoulin	2
Thunder Bay	64
Kenora	15
Rainy River	11
Prince Edward	1
Lambton	21
Total	2 795

4. TECHNOLOGY ASSESSMENT

The PCB Working Group assessed technologies or facilities that would be necessary to destroy PCB wastes at OWMC. Under OWMCs mandate, the facility must be capable of managing all PCB wastes that will be generated in Ontario. Therefore, the existing facility design was reviewed to assess that:

- PCB liquids (high and low level)
- PCB solids
- PCB contaminated equipment

would be adequately managed. If the existing facility design was inadequate to manage some PCB wastes, recommendations and designs for modifying the facility were made. This work was conducted by Monenco Limited with input from Dillon. Waste types and quantities used for determining technology requirements are as discussed in Sections 2 and 3. The detailed report of PCB technology requirements is shown in Appendix B. The report includes schematic diagrams of facility modifications recommended to handle all PCB wastes. The PCB waste management requirements and recommended technologies are overviewed below.

4.1 PCB Waste Management Requirements

As discussed, there are basically three-types of PCB wastes that must be managed at OWMC:

- PCB liquids
- PCB solids
- PCB equipment

The rotary kiln incinerator proposed in the existing facility design is capable of destroying PCB liquids and small PCB solids, smaller than a 45 gallon drum. The incinerator efficiencies will meet all requirements for PCB destruction as described in Ontario regulations.

The existing facility design is inadequate for handling equipment carcasses that are contaminated with PCB and PCB capacitors. This is primarily because this equipment is large and cumbersome and is primarily metal contaminated with small quantities of PCB.

It was also found that there is no facility in existence in Canada to handle this PCB contaminated equipment.

A PCB decontamination facility has been designed to accommodate the equipment. The detailed technology report is appended in Appendix B. At the facility, equipment carcasses will be:

- Rinsed with No. 2 fuel oil to remove residual PCB.
- Internals will be removed and disassembled. All contaminated fibrous material will be incinerated and metal or ceramic decontaminated using No. 2 fuel oil, or thermal volatilization as applicable.
- Carcass 'box' will be size reduced using mechanical shears.
- Metal and ceramic pieces will be decontaminated as above.
- All decontaminated metal is proposed to be recycled.

- All decontamination fluids will be incinerated when PCB contaminated.

PCB capacitors must be shredded prior to incineration. As the capacitors cannot be drained prior to destruction, greater than 60% of the PCB in capacitors are absorbed on the paper internals of the capacitor, the shredder must be integral to the incinerator. As such, this type of shredder has been designed as part of the decontamination facility.

A schematic and detailed description of the decontamination facility is shown in Appendix B. As can be seen, the facility is designed to accommodate all sizes of capacitors transformers and other PCB contaminated equipment equal to or smaller than a 10 MVA transformer in size. It should, therefore, be adequate to manage the majority of the equipment that will require disposal at OWMC. It is recognized that some equipment may be too large to be handled at the facility. This should occur only rarely. In these instances, the equipment may have to be handled on-site. Consideration has been given to developing a mobile equipment decontamination facility in the future.

It should also be noted that a 15 year destruction period has been proposed in Appendix B for the management of PCB wastes at OWMC. This 15 year period was chosen to be consistent with other OWMC assessments and is considered conservative for PCB wastes. The PCB Working Group considers, however, that PCBs will actually be available for destruction at the rate and over the time period described in Section 3 of this report.

appendices

APPENDIX A
ESTIMATION OF FUTURE QUANTITIES OF HIGH LEVEL PCB'S REQUIRING OFF-SITE DISPOSAL

APPENDIX A
ESTIMATION OF FUTURE QUANTITIES OF HIGH LEVEL PCB'S REQUIRING OFF-SITE DISPOSAL

These notes outline the methodology and data used in the estimation of the number of transformers and capacitors currently in use, and the PCB's they contain, that are expected to require off-site disposal in the reference years, 1992 and 1997. The estimated quantities are also summarized.

A.1 Methodology

The in-service life of transformers and capacitors can be represented by a logistic attrition function such as the one developed for the Canadian Council of Resource and Environment Ministers (CCREM 1987, Appendix III) and a shown as Figure A.1. This function shows the 'normal' rate of attrition due to equipment failure. Given the number and age profile of transformers and capacitors in use, and an estimate of the half-lives of the equipment, it is possible to use the attrition function to estimate the future number of transformers and capacitors that will require disposal. This methodology was adopted in the present exercise. Information on the quantity of PCB per transformer and capacitor was then combined with the numbers of units to estimate the quantity of PCB waste requiring disposal.

As well as examining the implications of the normal attrition rate, an accelerated attrition rate was considered. For this purpose, it was assumed that 14% of all transformers in service between 1992 and 1997 would be phased out in addition

to those being retired normally. These are the transformers reported to be in sensitive and insecure indoor locations at the national level (CCREM, January 1987). The same percentage was assumed to apply to Ontario.

A.2 Data

A.2.1 Transformers

The number and period of installation of askarel transformers installed in Ontario are shown in Table A.1 and the size distribution of these transformers is given in Table A.2. These estimates are based on "National Inventory of Fluids Containing Polychlorinated Biphenyls (PCBs) (1985 Summary Update)" and a review of major transformer manufacturers records (Dillon). The estimated average volume of askarel by size class is shown in Table A.3.

The number of askarel transformers installed in Ontario, as estimated using industry production records, is somewhat different from inventory totals reported by the Ministry of the Environment, Environment Canada and Ontario Hydro. This difference can be accounted for by estimation errors, non-reporting of askarel in storage or in use, or the possible transport of transformers across the border. The Ministry of the Environment is currently revising their in-storage inventory data and expect that total PCB's reported in storage will increase.[1]

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1. Personal communication from MOE staff.

TABLE A.1
ASKAREL TRANSFORMERS INSTALLED IN ONTARIO

Time Period of Installation	Per Cent Total	Number of Units
Prior to 1936	Negligible	Negligible
1936 - 1940	1%	66
1941 - 1945	4%	264
1946 - 1950	5%	330
1951 - 1955	10%	660
1956 - 1960	16%	1,056
1961 - 1965	20%	1,320
1966 - 1970	22%	1,452
1971 - 1975	18%	1,188
1976/1977	4%	264
After 1977	Negligible	Negligible
TOTAL	100%	6,600

Reference: Dillon

TABLE A.2
SIZE RANGE OF ASKAREL TRANSFORMERS IN ONTARIO

Size Class	Volume of Askarel (Imp. Gal.)	Overall Dimensions (inches) Not to Exceed* H W D
Small	5 - 150	54" x 48" x 30"
Medium	151 - 500	108" x 96" x 72"
Large	501 - 1000	144" x 180" x 84"

* Overall dimensions do not include external accessories that can be removed before storage.

Reference: Dillon

TABLE A.3
AVERAGE SIZE OF ASKAREL TRANSFORMERS IN ONTARIO

Size Class	Imperial Gallons of Askarel	Percent of Total
Small	60	12.5%
Medium	300	80.8%
Large	700	6.7%

Note: This distribution has been changing over the years. Practically all large askarel transformers were installed after 1950.

Reference: Dillon

The typical half-life of askarel transformers is considered to be 35-40 years (Dillon). It was found that an assumed half-life of 35.8 years gave an estimated 4,763 transformers in use in 1987 which is consistent with information provided by Environment Canada and Ontario Hydro. This value for the half-life was used to generate the results reported below.

A.2.2 Capacitors

The number and period of installation of PCB-filled capacitors installed in Ontario are shown in Table A.4. As in the case of transformers, the figures presented have been estimated using industry production records.

APPENDIX A.4
PCB FILLED CAPACITORS INSTALLED IN ONTARIO

Period of Installation	Percent of Total	Number of Units
1936 - 1940	5%	4,000
1941 - 1945	6%	4,800
1946 - 1950	8%	6,400
1951 - 1955	9%	7,200
1956 - 1960	10%	8,000
1961 - 1965	12.5%	10,000
1966 - 1970	14.5%	11,600
1971 - 1975	20%	16,000
1976/1977	15%	12,000
TOTAL	100%	80,000

Reference: Dillon

An average size of 0.02 tonnes per capacitor has been estimated for the purposes of this study (Dillon).

The half-life of capacitors is considered to be about 25 years (Dillon). However, it is reported that there are 55,079 capacitors in use (Environment Canada, Ontario Hydro) which is consistent with a half-life of 35.9 years when the logistic model is used to estimate normal attrition. This value of a 35.9 year half-life was employed in the estimates of future attrition reported below.

A.3 Results

Table A.5 summarizes the estimates of transformers and capacitors that will require off-site disposal in 1992 and 1997 if the 'normal' rates of attrition, as predicted by the logistic model, are followed. The table also provides estimates of attrition rates for an accelerated phase out of transformers in sensitive and insecure indoor locations. The estimated number of additional transformers and capacitors that will be taken out of service between 1988 and 1991 are shown in Table A.5 with the associated estimates of PCB waste requiring off-site disposal. As there is no disposal facility currently available, these are expected to go into storage and be potentially available to OWMC upon plant start-up.

TABLE A.5
ESTIMATES OF TRANSFORMERS AND CAPACITORS REQUIRING OFF-SITE DISPOSAL

	1988-1991		1992		1997	
	Number Units	Quantity (tonnes)	Number Units	Quantity (tonnes)	Number Units	Quantity (tonnes)
NORMAL ATTRITION						
Transformers						
Small	86	35	21	9	25	10
Medium	554	1132	139	283	160	328
Large	48	228	12	57	15	70
Total	688	1396	172	349	200	407
Capacitors	6691	134	1673	33	1890	38
Total PCBs	n/a	1530	n/a	382	n/a	445
ACCELERATED ATTRITION						
Transformers						
Small	86	35	21	9	38	16
Medium	554	1132	139	283	248	507
Large	48	228	12	57	23	108
Total	688	1396	172	349	309	630
Capacitors	6691	134	1673	33	1890	38
Total PCBs	n/a	1530	n/a	382	n/a	668

Note: Totals may not add due to rounding.

APPENDIX B
TREATMENT OF PCB CONTAMINATED ELECTRICAL EQUIPMENT

SECOND DRAFT

TECHNICAL PAPER

DECONTAMINATION OF PCB CONTAMINATED ELECTRICAL EQUIPMENT

Prepared by

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One St. Paul Street
St. Catharines, Ontario

4 November 1988

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6.0 CONCLUSIONS

1.0 INTRODUCTION

This study was initiated to identify, evaluate and recommend the most suitable technology to meet OWMC's requirements for the decontamination of PCB contaminated equipment such as transformers, capacitors, electric magnets, pole-mounted regulators and bushings from transformers.

Suitable technologies include decontamination at the storage site and destruction of the carcasses at a private facility (such as a steel foundry); decontamination with destruction or direct disposal of carcasses at the OWMC facility; and decontamination at the OWMC facility, component breakdown and direct recycling of the metals.

Monenco's scope of work, as part of the Technology Working Group, was to evaluate alternative technologies which are suitable for decontaminating the equipment at the OWMC facility, and therefore this report is limited to that particular application.

Quantitative and dimensional information was provided by the Quantities Working Group for estimating equipment and building size requirements.

Although the technology evaluation for this study is limited to PCB contaminated electrical equipment, the description of the PCB Building in section 5.0 also includes provision for handling PCB contaminated liquids and solids. One building will provide a single location on the site where all forms of incoming PCB waste, whether liquid, solid or equipment can be handled.

2.0 DESIGN BASIS AND ASSUMPTIONS

The following quantities and sizes of PCB contaminated equipment were provided by M. M. Dillon Limited:

1. Transformers (askarel filled)
   Quantity: 6050 units, of which:

   12% are considered "small" in size, and
   contain between 23 and 680 litres of PCB fluid
   max. weight - 2270 kg (incl. fluid)
   max. dim. - 1370 mm x 1220 mm x 760 mm

   81% are considered "medium" in size, and
   contain between 681 and 2275 litres of PCB fluid
   max. weight - 9100 kg (incl. fluid)
   (generally in range of 4500 - 7250 kg)
   max. dim. - 2750 mm x 2440 mm x 1830 mm

   7% are considered "large" in size, and
   contain more than 2275 litres of PCB fluid
   max. weight - 18 200 kg (incl. fluid)
   (generally in range of 13 500 kg)
   max. dim. - 3660 mm x 4580 mm x 2140 mm

   The dimensions assume bushings are detached.

2. Capacitors
   quantity 68 375 units
   average dimension 610 mm x 305 mm x 610 mm

3. Other (Bushings, Electromagnetics, Regulators, Switches, etc.)
   quantity 80 units

4. Paper Insulated Lead Covered Cable
   1000-1500 km

5. Ballasts

quantity 2 250 000 - 30 000 000 units

In addition to the above information, the following criteria and assumptions also form the basis for the technology evaluation and conceptual design.

- Even though the largest transformer expected is 5 MVA, space and capacity allowances are made to handle transformers up to 10 MVA in size.

- In order to prevent the possibility of generation of secondary contaminants within the PCB building, thermal methods such as flame cutting will not be utilized for technologies which require reduction in size of transformers. Mechanical methods such as shears will be used.

- Current MOE regulations have a 50 ppm PCB concentration allowable limit. As these limits are under MOE review, stricter limits are anticipated and therefore, suitable evaluated technologies must produce significantly better results than current limits.

- Transformers too large to be transported in overpack drums will be drained prior to shipment to OWMC.

- Capacitors shipped to OWMC will contain the PCB liquid.

- The electrical equipment identified above will be decontaminated over a fifteen year period.

3.0 IDENTIFICATION OF SUITABLE TECHNOLOGIES

The following long list of potential technologies was developed from a computerized search of several databases, literature reviews and a telephone survey:

- o Landfill
- o Retrofill
- o Rotary Kiln Incineration
- o Plasma Pyrolysis
- o Infrared Pyrolysis
- o Molten Salt Incineration
- o Molten Glass Furnaces
- o Electric Arc Furnaces
- o Thermal Volatilizer
- o Solvent Extraction

A short description of each technology follows:

Landfill

This involves the burial of pieces of electrical equipment in a secure or chemical landfill and is the most widely used method in the United States for disposal of transformer carcasses. The carcasses are drained and normally flushed with a solvent prior to landfilling.

Retrofill

In its basic form, retrofilling involves the draining of the existing fluid from a piece of electrical equipment and replacement with new, non-contaminated fluid. The refilling is repeated as many times as necessary to reduce the PCB contamination level in the fluid to 50 ppm or less.

Current practice, however, does not rely on repeated draining and refilling to achieve the desired decontamination level. For equipment containing PCB contaminated mineral oil, the equipment, normally a transformer, is connected to a mobile processing unit. A sodium based or polyethylene glycol (PEG) reagent is used to dechlorinate the PCB in the oil as it circulates through the processing unit. This allows the dechlorinated oil to be reused and the equipment is then reclassified as being non PCB.

Since 1986, several organizations have developed a similar process for askarel filled equipment. In this process, however, the PCB in the askarel is neither dechlorinated nor destroyed and the askarel is therefore not reused. The askarel is first drained from the equipment and either put in storage or shipped off-site to an approved incineration facility. The electrical equipment is refilled with new fluid, connected to a mobile processing unit and the fluid circulated through both the processing unit and the equipment. The circulating fluid leaches or extracts the remaining PCB's from the equipment internals and the extracted PCB's are then separated, normally by vacuum distillation. The processing unit remains connected until testing proves that the leach-back rate of the remaining PCB's has been reduced to an acceptable level, which typically takes 3 to 5 months. At this point the circulating fluid is drained and the equipment is filled with new permanent fluid and placed back into service.

These processes are not applicable to sealed electrical equipment such as capacitors.

Rotary Kiln Incineration

Although rotary kilns are capable of accepting pieces up to the size of a 55 US gallon drum, electrical equipment is normally reduced in size prior to being fed to the kiln to ensure maximum contact of the equipment internals with the kiln's combustion environment. The equipment pieces are considered a normal waste feed stream to the kiln but the kiln temperature must be accurately maintained in accordance with the relevant regulatory requirements during PCB incineration.

Any residual PCBs are volatilized in the kiln and destruction of the gaseous phase components is normally completed in a secondary chamber or after-burner. In addition, any organic matter from the equipment internals is oxidized and the remaining metallic pieces are discharged along with other waste residues from the kiln. The metal can be either landfilled or shipped to a scrap metal recycler.

A rotary kiln is the proposed incineration technology for OWMC's organic wastes; full details are provided in the Incineration Process Area Report.

Plasma Pyrolysis

An electric arc is used to create a plasma, which is a high temperature, ionized gaseous mass whose temperature can exceed 5000°C. Temperatures of this magnitude can completely dissociate PCB's and other waste components into their basic atomic components. The arc furnace is operated in a pyrolytic, or oxygen deficient, mode to reduce the amount of flue gas which will require subsequent treatment.

A demonstration unit constructed in Model City, New York was designed to accept whole capacitors without prior size reduction. The capacitor casings are completely melted in the furnace and require tapping off of the molten metallic slag pool. Any evolved gas travels through the plasma above the slag pool before leaving the furnace and is subsequently cooled, scrubbed and any combustible components flared.

Infrared Pyrolysis

The infrared system involves a radiant surface transferring thermal energy in the infrared range of the spectrum to the waste being processed. The infrared range is one of the most efficient ranges in the spectrum for the transfer of such energy.

The radiant surface is typically composed of a number of electric powered silicon carbide or graphite tubes known as glow bars. Waste, which in the case of electrical equipment would require prior size reduction, is introduced into a primary chamber radiant zone where it is baked under the glow bars to volatilize and partially destroy the organic contaminants in the solid waste. The gas produced in the primary chamber is directed to a secondary chamber to complete the combustion. The secondary chamber could also be an infrared furnace but is generally a conventional, fossil fuel fired furnace.

As with plasma pyrolysis, the primary radiant chamber is operated in a pyrolytic condition to reduce the amount of gas requiring subsequent treatment. Since the energy in the primary chamber is radiant, there are very low particulate emissions in the gases leaving the primary chamber.

Molten Salt Incineration

This process uses a molten bed of salt, such as sodium carbonate, as a heat transfer and reaction medium. Waste and air are introduced beneath the surface of the molten salt bed which is contained in a combustor or reaction vessel and any gases formed during combustion are forced to pass through the molten salt bed before exiting the combustor. One advantage claimed for this process is that any acid gases formed during combustion react with and are absorbed by the bed, so reducing or possibly eliminating the need for downstream scrubbing. Further, since the process employs lower temperatures than conventional incineration techniques, the formation of NO_x compounds is not a concern.

Molten Glass Furnaces

These types of furnaces are common in current glass making technology. PCB contaminated waste could be introduced into the molten glass bed in the furnace where the organics would be volatilized and at least partially destroyed. Inorganic solids would dissolve in the glass bed and be bound in the stable glass matrix to form a non leachable residue. Since these units are sold as commercial, chemical processing units and not as incinerators their use might involve various modifications such as measures to prevent gas escapes, post furnace combustion chambers and scrubbing of gases evolved in the furnace.

Electric Arc Furnaces

Electric arc furnaces have been utilized in the steel making industry for some time. Unlike the plasma pyrolysis unit which uses DC current, conventional steel-making arc furnaces use alternating current to produce an arc between electrodes inserted through the furnace roof.
The heat generated by this arc is used to melt the ore and/or scrap iron charge. As noted with the molten glass furnaces mentioned above, these units would probably require modifications to allow their use as incinerators.

Thermal Volatilizer

A conventional fuel fired, refractory lined furnace or roaster could be utilized to volatilize and drive off all organic contaminants in the electrical equipment. The furnace would only be required to operate at a

sufficient temperature to ensure volatilization of the organics and the gases could be ducted to a secondary combustion chamber or after burner that would be operated at a temperature sufficient to ensure the destruction of PCBs.

Another form of thermal volatilizer is an electrically heated vacuum autoclave, which is a technology currently used in Europe. As for the furnace or roaster, residual PCBs are volatilized and ducted to a secondary combustion chamber for destruction.

The decontaminated equipment carcasses from either process are suitable for landfill or recycle.

Solvent Extraction

In this process, PCB's adsorbed on the metallic surfaces or absorbed in the composite organic internals of electrical equipment would be leached by a solvent that would preferentially dissolve the PCB. This could be accomplished either by circulating the solvent through the equipment or by immersing the equipment or pieces of the equipment in a solvent bath. The process could be designed to either decontaminate batches or be a continuous process. Further, depending on the solvent selected, it is possible that this could be reused after separating the extracted PCB's in a distillation column.

The extraction of one or more components from a solid or solid-liquid matrix is a well established industrial process.

4.0 TECHNOLOGY EVALUATION

An evaluation of the technologies described in the previous section and a selection rationale is presented in this section.

Landfill

Although this is the current practice for disposal of transformer carcasses in the U.S., the environmental threat posed by the residual PCBs in the carcasses is of increasing concern. Further, Canadian and Provincial environmental ministries do not permit this practice and, therefore, this technology is considered unacceptable.

Retrofill

This technology is proven and will continue to be applied to equipment, specifically transformers, which have a reasonable service life remaining; have been specially designed or are in inaccessible locations which make replacement difficult if not impractical. In the case of transformers with PCB contamination levels of 1000 ppm or less, this technology will normally represent the most economic solution for the transformer owner.

Currently, a number of commercial organizations offer this technology and its selection by OWMC would involve competing in an existing market. Further, the market appeal of this technology is primarily its mobility, and it would thus not be suitable for OWMC's fixed, regional, facility.

Rotary Kiln

High temperature thermal incineration is one of the generally accepted methods for the destruction of PCBs. The rotary kiln is one of the most flexible types of incinerator, being capable of handling a wide variety of waste forms, with a proven performance record. It can also be considered one of the most viable technologies for the destruction of PCB contaminated solids. Many mobile and fixed installations in North America and Europe successfully incinerate PCB wastes.

Plasma Pyrolysis

This technology is far from being proven, although it promises greater destruction efficiencies than those available from conventional incinerators. Development problems currently being encountered preclude its consideration as a feasible alternative for OWMC's facility at the present time.

Infrared Pyrolysis

This technology has proved its destruction capability on PCB contaminated soils and although it has not been tried on pieces of contaminated electrical equipment, there are no apparent technical reasons why it could not also effectively pyrolyze the PCB's in such waste. The units developed to date have been designed to be mobile, but there appears no reason why a stationary unit could not be constructed. Thus, from a technical viewpoint, inclusion of this technology in the OWMC facility would be possible. The developer and supplier of this technology, Shirco Infrared Systems Incorporated, have however declared bankruptcy.

Molten Salt Incineration

To date, this technology has only been demonstrated on a bench scale level. Further, the tests done to date have not included the introduction of waste that is primarily metal. In one test run during an optimization program conducted by Rockwell International, the technology developer, for the Canadian Electrical Association, contaminated solid waste containing 4% PCB's by weight and equal percentages of polyethylene, paper, and aluminum metal were fed to the combustor, with promising results.

The current state of this technology was, however, not considered as a practical option for OWMC.

Molten Glass Furnaces

Using commercial glass furnaces would, as noted previously in section 3, require some modifications and/or equipment additions. It would also require the acceptance of additional liabilities by the furnace operator which would probably be incompatible with the commercial interests of making glass.

The Electromelt Pyro-Converter developed by Penberthy Electromelt International uses an electrically heated glass furnace and is available commercially. However, with either this type or commercial glass furnaces, it is questionable if a molten glass pool could be maintained with a predominantly metal feed and, therefore, if a non-leachable glass matrix would be formed when the furnace's discharge cooled and solidified.

This technology cannot therefore be considered proven for the specific purpose of destroying PCB contaminated electrical equipment.

Electric Arc Furnaces

Use of commercial steel making electric arc furnaces is subject to the same limitations as the commercial glass furnaces discussed above. Further, documented testing of any commercial unit for this application was not available and therefore this technology was not considered a practical option for OWMC.

Thermal Volatilizer

This option is feasible, from a technical point of view, although trial runs would probably be required to substantiate its performance. The concept is currently being studied by the Alberta Special Waste Corporation for inclusion in their facility at Swan Hills.

At El Dorado, Arkansas, Ensco have a barrel roasting furnace in which they have roasted pieces of transformer carcasses under a research permit and have achieved results of less than 2 ppm of PCBs on the metal.

In France, Tredi volatilize PCBs from transformer carcasses and internals in electrically heated autoclaves. (It should be noted that they also utilize static and rotary kilns for PCB and other organic wastes.)

If OWMC were to incorporate a thermal volatilizing unit, the gases evolved could be ducted to the secondary combustion chamber which follows the proposed rotary kiln.

Solvent Extraction

As noted in section 3, solvent extraction is a well established industrial process. While it has not been applied on a large scale for the decontamination of electrical equipment, several test programs have been conducted into this application and solvent extraction has been used in the decontamination of buildings and their contents after fires involving PCBs. The possibility of solvent reuse and the fact that this process is less energy intensive than high temperature thermal destruction methods are additional attractive features.

It is therefore felt that this technology could be applied to the decontamination of electrical equipment.

Selected Technologies Rationale

Based on the above evaluation of technologies it was concluded that the technologies which could be utilized by OWMC at its facility were:

- o Rotary Kiln Incineration
- o Infrared Pyrolysis
- o Thermal Volatilizer
- o Solvent Extraction

A rotary kiln incinerator is currently proposed for the OWMC facility for the destruction of organic wastes, which include PCB liquid and drummed (soil, rags, etc.) wastes. Also, there is a proven track record of shredding and feeding capacitors to rotary kilns. Therefore, to utilize the preferred incineration technology to the furthest extent, it is recommended that each of the wastes noted in this paragraph be destroyed in the rotary kiln.

There is, however, a limit on the amount of metal that can be fed into the kiln. This results from two concerns: the kiln fill factor and kiln refractory life. The kiln fill factor is the percentage volume of the kiln that is occupied by solid material and therefore unavailable for the flue gas to evolve. If the kiln's design fill factor is exceeded, the smaller gas space increases flue gas velocity, reduces gas residence time in the kiln and this can affect the flue gas composition leaving the kiln. In

addition, as gas velocity increases, particulate carry over from the kiln also increases. The amount of metal fed to the kiln also leads to shortening of refractory life due to the continuous impact of metal on the refractory.

Monenco are awaiting data from the Incineration Technology Consultant regarding the amount of metal which can be fed into the kiln, however it may not be desirable to incinerate transformer carcasses and internals due to the revenue received for recycling (particularly copper internals) and it is difficult to reduce the carcasses to the size required for feeding to the kiln.

Also, if significant amounts of contaminated lead cable is received, it would be more practical to decontaminate this by other means than incineration due to the possible discharge of lead oxide particulates. Therefore, other technology(ies) are required to supplement rotary kiln incineration. Of the methods noted as suitable technologies at the beginning of this section, thermal volatilizer and solvent extraction are the most preferred.

Even though infrared pyrolyzer is somewhat similar to thermal volatilizer, financial problems have curtailed its development. It is therefore not further considered at this time.

It is currently recommended that the facility contain both thermal volatilizers and a solvent extraction system for the following reasons:

- o even though large transformers will be drained prior to shipment to OWMC, solvent flushing is required prior to dismantling to remove as much PCB residue as practical to make the disassembly and size reduction safer for workers;

- o thermal volatilization is a cleaner process for fairly large metal pieces than subsequent solvent extraction baths;

- o solvent extraction may be more suitable for lead cable and other miscellaneous types of contaminated electrical equipment;

- this study has not been performed in sufficient depth to ascertain eccnomic comparison of the two methods;

- prior to detail design of the plant, the development of the technologies may clearly indicate a preference to one.

It is therefore considered that thermal volatilization and solvent extraction be considered as alternative/complementary technologies pending final decision during the detailed design phase of the project.

Evaluation of Solvents for Solvent Extraction

For the solvent extraction system, the selection of solvent used for decontaminating the metal components of the transformers must be carefully evaluated as many factors such as predicted cleanliness of metal, proven use for decontamination, annual quantity of solvent required, potential safety hazards to environment and personnel, potential to recover/recycle solvent and cost must be considered. For purposes of this technology evaluation, two classes of solvent have been considered: halogenated solvents (such as trichloroethylene, perchloroethylene, trichloroethane and freons) and No. 2 fuel oil. A comparison of the two classes of solvents is as follows:

Halogenated Solvents

Advantages	Disadvantages
PCB's can be readily separated from contaminated solvent (by distillation) and solvent reused.	Higher investment cost due to solvent recovery.
Generally non-flammable.	High vapour pressure resulting in higher air emissions. May have higher toxicity requiring air emission control.
More effective than No. 2 fuel oil as washing/flushing agent.	May have higher toxicity requiring air emission control.
Due to recycle, annual quantities of solvent are minimized.	High cost (may be offset by lower quantity required).

No. 2 Fuel Oil

Advantages	Disadvantages
Lower investment cost due to no recovery facilities.	Not suitable for separation of PCB's and recycle of solvent.
Low vapour pressure resulting in low air emission. Also has low toxicity.	Flammable.
	Annual quantity requirements are high resulting in high cost (May be offset by low unit cost or may be used as fuel for kiln, however it would increase throughput through the kiln.)
	May not be as effective as halogenated solvent.

Each of these types of solvent has been used successfully by various research and commercial organizations for the decontamination of metal. As well as for transformer decontamination, solvent cleaning has also been used for PCB fire clean-ups.

For purposes of this study, No. 2 fuel oil has been selected as the proposed solvent since the use of halogenated solvents would raise concerns related to the occupational health and safety of the employees. While occupational health and safety concerns are important, so are those associated with minimizing amounts of on-site generated wastes. These would be greater when fuel oil is used as a solvent, as it is not suitable for recycle. Therefore, a more detailed evaluation of the advantages/disadvantages of suitable solvents is required to arrive at a net result.

5.0 DESCRIPTION OF PCB BUILDING

This section of the report provides a plant description for the chosen technologies selected in the previous section. An isometric flow diagram and building layout are also included.

The conceptual design of the building allows for handling/processing of the following:

- PCB liquids delivered in bulk carriers or drums;
- PCB materials (contaminated soil, clothes, etc.) delivered in drums;
- PCB equipment (such as transformers and capacitors).

The major factor in determining the PCB Handling Building size is the storage/handling space requirements for the PCB electrical equipment. The following quantity estimates were provided by M. M. Dillon Limited:

capacitors	68375 units
transformers (askarel)	6050 units

Assuming that all of these units could be decontaminated over a 15 year period and the PCB equipment would be processed 5 days per week/one shift per day, the number of units processed daily would be:

capacitors	19
transformers	2

If a three week inventory of the electrical equipment is to be stored, the building must be capable of storing 285 capacitors (allowance of 100 m^2) and 30 transformers (allowance of 200 m^2). An allowance of 100 m^2 has also been made for the storage of drums containing PCB liquids and material.

A truck aisle is provided for the delivery of electrical equipment and drummed PCB waste. Transformers will be unloaded from the trucks and put into storage with an overhead crane. Capacitors and drums will be unloaded from trucks and put into storage by forklift truck. Depending on the size of the capacitors, some may be shipped in drums but, in any event, suitable attachments will be provided for the forklift truck to accommodate the full range of drum/capacitor shipping modes.

Capacitors and drums will be retrieved from storage by forklift and placed on roller conveyors, those containing solid waste being conveyed directly to the shredder. Drums which contain liquid will be emptied at the drum pumpout station prior to being conveyed to the shredder. The liquid pumped out of the drums will be collected in the vacuum receiving tanks and transferred to the segregated organic storage tanks.

The shredding station will include an elevator to lift the drums/capacitors to the level of the shredder inlet hopper. The shredder, located directly below the inlet hopper, will be of the slowly rotating shear type with two counter-rotating shafts which will reduce the metal to thin strips. A retention hopper located beneath the shredder will provide surge storage capacity. The shredded product will be fed into empty containers and conveyed to the rotary kiln. The shredder station will be sealed to prevent fume emission and blanketed with nitrogen to prevent explosion in the event of heat build-up in the unit.

Small transformers may either be decontaminated and recycled or processed in the same manner as capacitors, provided the metal content can be accommodated in the kiln. Larger transformers will be decontaminated and recycled for metal recovery. Small transformers delivered to the site in overpack drums will be drained prior to processing, while larger transformers will be drained prior to shipment to OWMC. The first step of the process will be to move the drained transformer to the flush area using the overhead crane. There it will be flushed with solvent (No. 2 fuel oil) to remove residual contaminants and reduce the PCB level to a sufficiently low level to safely dismantle the transformer. The flushing cycle may take up to 48 hours to sufficiently clean the transformer.

Upon completion of the flush (and swab cleaning of exterior, if required), the transformer will be moved to the dismantling area, and the cores and ancillaries removed. The cores will be disassembled and the composite materials (paper, wood, etc.) sent to shredding/incineration. Even though stripping the cores will be a rather messy, labour intensive process, the separation of metal from composite materials and a further

reduction in size of metal will allow more effective decontamination. Also, if the metal is to be recycled, scrappers would prefer to receive metal only.

The transformer carcasses and metal cores will be moved to the reduction area where they will be reduced to manageable sized pieces. The equipment utilized in this area will be of a mechanical type such as shears. Thermal reduction equipment such as flame cutters will not be used to avoid generation of secondary contaminants. After size reduction, the carcass and core pieces will be forwarded to the thermal volatilizers.

After thermal volatilization, the metal will be ready for recycle/landfill.

The decontamination of transformers is a largely labour intensive process requiring various movements about the area. In addition to the overhead crane, materials handling equipment such as hoists on monorails, etc. will be provided at suitable locations to facilitate the required transfers.

Items such as lead cable and other miscellaneous electrical equipment will be handled in the same area as the transformers. Splitters and cutters will be provided to separate shield and insulation from the lead cable. Suitable reduction equipment will also be provided for miscellaneous equipment. Metal components will be decontaminated and composite materials will be forwarded for incineration.

Items such as lead cable which require solvent wash will be forwarded to that system for decontamination. Subsequent to solvent wash, the metal will be dried and then placed into containers for recycle/landfill.

It is estimated that the cleaned metal by both the thermal volatilization and solvent extraction systems will have residual PCB levels far below the current 50 ppm regulation of the MOE, and may actually achieve levels as low as 2 ppm.

The solvent flush/wash process will consist of two parts:

- o closed recirculation of solvent through the transformers in the transformer flush area until the PCB content of the solvent has essentially stabilized;

- o a two-stage solvent immersion process to wash the lead cable and other miscellaneous components as required.

Storage tanks for clean solvent, recirculating solvent and contaminated solvent, with transfer/recirculating pumps and including an allowance for the future addition of a batch still, will allow efficient operation of the system to obtain maximum cleanup of PCBs while using a minimum of solvent.

The solvent system is a continuous process which maintains acceptable levels of PCB contamination for each stage of the cleaning process. The PCB contaminated solvent is transferred in reverse order through the system to the transformers. Clean solvent is added to the second (final) solvent wash tank, the solvent from the second solvent wash tank is transferred to the first solvent wash tank, and the solvent from the first wash tank is transferred for use in the transformer flush procedure. When the level of PCBs in the transformer flush cycle has risen to a pre-set limit, the contaminated solvent will be transferred to the contaminated solvent tank and then to either the segregated organic storage tank or directly to the incinerator.

It is not practical to separate the PCBs from the contaminated No. 2 fuel oil, although if a different solvent is ever considered, addition of a batch still to the solvent system will allow recovery of the solvent for reuse.

Personnel protection will be emphasized in the PCB building to minimize the long term effects of exposure. The following safety measures will be incorporated in the design and operation of the PCB handling system and reinforced by regular checks to ensure that proper procedures are being maintained.

- o local exhaust ventilation at all points where PCB vapour mist and particulate is likely to be released;

- o storage break-up, trans-shipment and all in-between operations will be carried out according to Occuptaional Health and Safety procedures to be established prior to plant commissioning;

- o employee personal protective equipment selected and used in accordance with Regulations;

- o workplace air monitoring and ventilation effectiveness checks will be carried out as determined by a qualified industrial hygienist;

- o provide spill mitigation (curbs, drains, etc.) and establish clean-up procedures.

The proposed solvent, No. 2 fuel oil, is a kerosene with relatively low toxicity. Protective measures for this will be satisfied by the protective measures needed for PCBs.

The Segregated Organic Storage Tanks and a Bulk Unloading Bay will be located on the west side adjacent to the PCB Building. These facilities will be provided at this location so that all PCBs delivered to the site can be processed at the same location. Previously, the Segregated Organics Storage Area had been located north of the Incinerator Tank Farm.

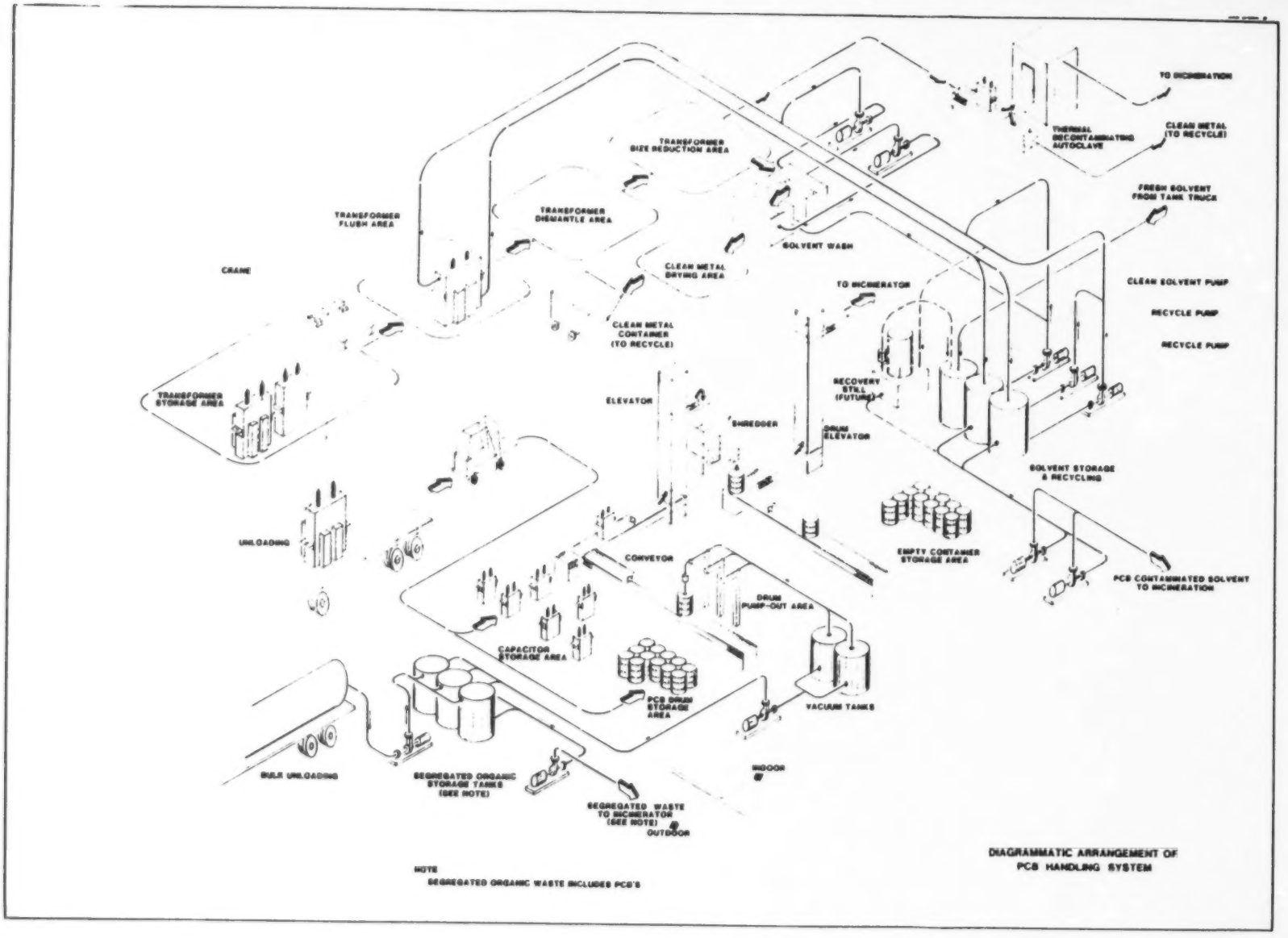
6.0 CONCLUSIONS

The previous sections of this report have provided a technology evaluation for the processing of PCB contaminated electrical equipment and a description of the proposed PCB Building. It should be emphasized that, until now, the only approved option in Ontario for PCB contaminated electrical equipment was storage while, in the United States, drained/flushed transformers have been landfilled. There has not been substantial experience in other methods of decontaminating electrical equipment and many of the technologies do not meet OWMC's "proven" technology requirement.

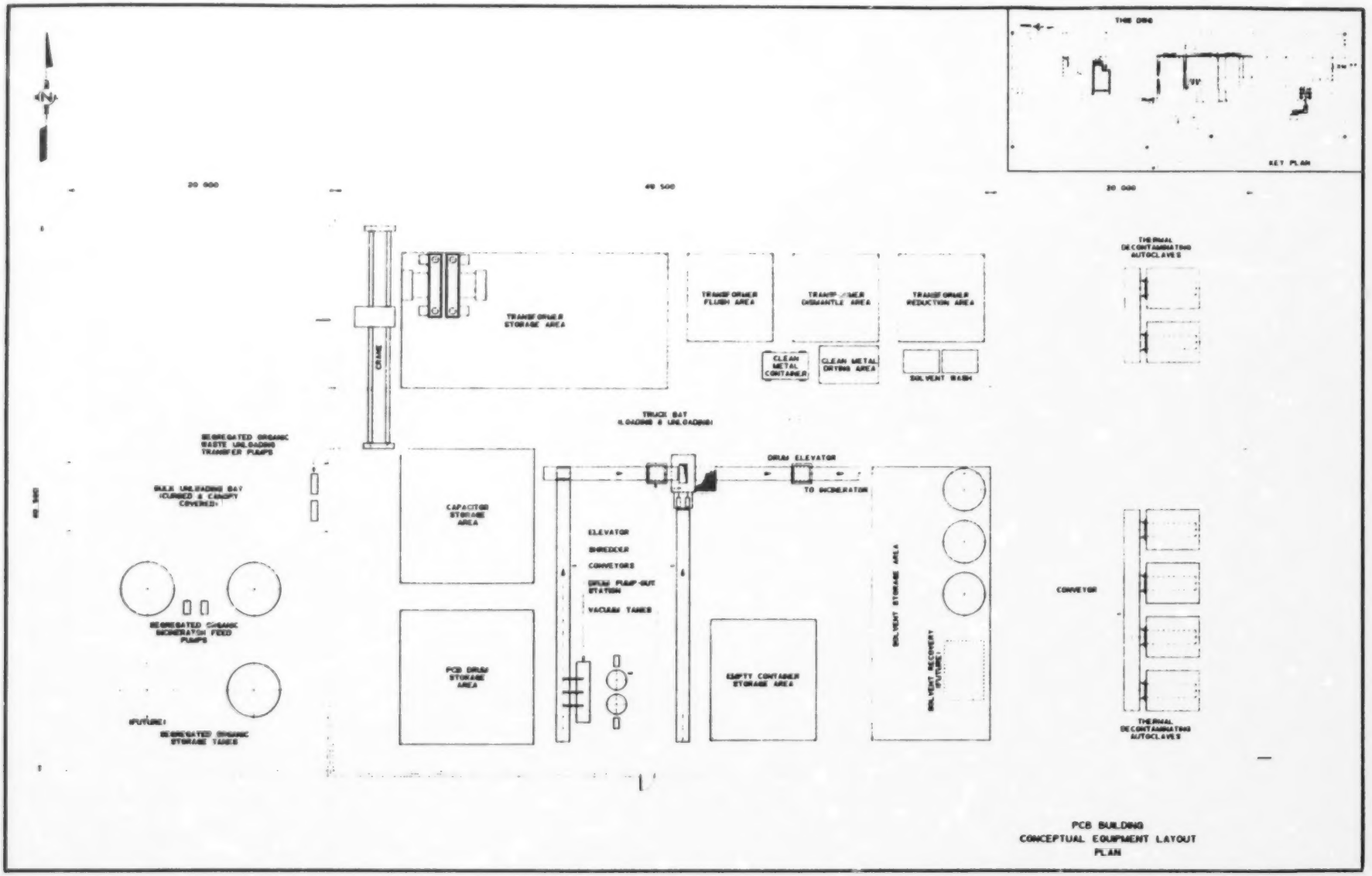
One of the technologies that has been applied successfully for several years is rotary kiln incineration. As this is the proposed technology for destruction of organic wastes, it is also proposed to the extent possible for PCB wastes. As described in the report, the PCB wastes which will be fed to the kiln include liquids, contaminated soils, drummed wastes and capacitors (shredded), and composite materials from transformers, cable and other electrical equipment.

Transformer carcasses, lead cable and other miscellaneous electrical equipment which cannot be fed to the rotary kiln require other suitable technologies. This study proposes thermal volatilization and solvent extraction as suitable technologies for these. The off-gases from the thermal volatilization will be incinerated in the secondary combustion chamber, and the contaminated solvent will be fed to the rotary kiln.

The PCB technologies described in this report are developed to a conceptual level only. Development of the technologies over the next few years (or emergence of other technologies) may necessitate changes to the proposal. Also, much more detailed work is required to confirm suitability of the technologies. As noted in the report, Monenco is currently in the process of obtaining further details for these.



DIAGRAMMATIC ARRANGEMENT OF PCB HANDLING SYSTEM



PCB BUILDING
CONCEPTUAL EQUIPMENT LAYOUT
PLAN